LEADING A PATH OF ITS OWN: CASE STUDY OF SUBADULT TIGER *PANTHERA TIGRIS* ESTABLISHING A TERRITORY IN BANNERGHATTA NATIONAL PARK, SOUTHERN INDIA[1]

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Bannerghatta National Park (BNP), a protected forest in southern India, historically has had only sporadic reports of tiger *Panthera tigris* presence, despite bordering known tiger habitats. This paper summarizes evidence collected from a tiger sighting in BNP over a nine-month period. The primary aim of this study was to identify the individual tiger for management purposes and to explore possible reasons for its presence in this new habitat. We employed various methods, including both direct and indirect documentation of the animal's presence and baseline behavioural observations, focusing on movement patterns and kills. The study identified the animal as a young male tiger with the potential to establish a home range within BNP. Notably, its movements were concentrated in BNP's northern region, and its range extended beyond protected area limits—likely due to the narrowness of the park, proximity to human settlements, and the large territory sizes typical for tigers. This case study provides baseline behavioural insights, which may indicate the resources essential for territory selection. It also highlights the importance of "stepping-stone" patches that are critical for carnivore dispersal and conservation across fragmented landscapes.

Key words: tiger ecology, behaviour, animal movement, novel territory, Bannerghatta National Park

INTRODUCTION

The IUCN has listed the tiger *Panthera tigris* as endangered, placing the species at the forefront of global conservation efforts. In India, the tiger serves as an umbrella species for diverse ecoregions (Anwar *et al*. 2014; Duangchantrasiri *et al*. 2016). Despite a strong public interest and policy emphasis on increasing tiger populations across range countries, many aspects of tiger behaviour and ecology, crucial for its conservation and management, are still being studied. A key factor in conservation is understanding resource use and movement between habitats. Animal movements are crucial for fitness, reproductive success, and genetic diversity (Gour *et al*. 2013), particularly for tigers, apex predators that require vast habitats to sustain viable populations. Prey abundance and resource distribution are primary determinants of species home ranges (Simcharoen *et al*. 2014); however, tiger movement across landscapes is also influenced by biological factors such as age and sex (Seidensticker *et al*. 1999; Smith 1993). Subadult dispersal is a significant life event affected by prey availability, population dynamics within a landscape, habitat continuity, and the need to maintain genetic diversity while avoiding inbreeding (Gour *et al*. 2013). Male tigers typically establish larger territories and disperse farther from their natal ranges, while females often prefer to stay close to their birthplace (Sarkar *et al*. 2021). Movement may also be driven by same-sex competition, displacing younger or older individuals (Carter *et al*. 2015).

Tiger movement patterns are further complicated by anthropogenic pressures. The species' geographical range has shrunk significantly in the past 50 years, now covering only about 7% of its former range (Mondal and Nagendra 2011). Understanding how tigers adapt their movements within these changing landscapes is therefore critical. Non-protected areas can also support tiger populations (Variar *et al*. 2023), making it vital to study tiger use of connected habitats or other landscapes surrounding primary tiger habitats for effective conservation management.

Approximately 65% of India's estimated 2,967 tigers are located in designated tiger reserves (Jhala *et al*. 2020), protected areas focused on species management and

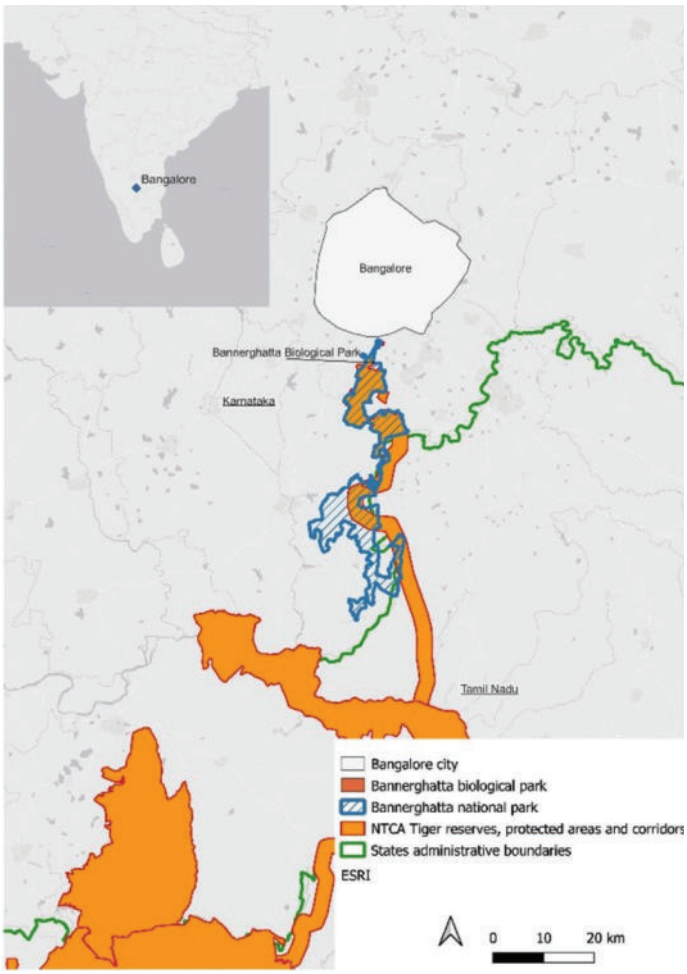

Fig. 1: Bannerghatta National Park boundary (outlined blue) in relation to the adjoining National Tiger Conservation Authority (NTCA) identified tiger reserves, protected areas, and corridors (orange). The green lines indicate administrative boundaries of the states of Karnataka (West) and Tamil Nadu (East)

conservation (Gubbi *et al*. 2017). The largest global tiger population is found in the interconnected protected areas of Nagarahole-Bandipur-Mudumalai-Wayanad within the Western Ghats landscape (Jhala *et al*. 2015). This landscape is linked by fragmented corridors to Cauvery Wildlife Sanctuary (CWS) and BNP, which is situated at the northeastern terminus of this forest complex (Fig. 1). While CWS hosts tigers (Gubbi *et al*. 2017), BNP previously only had historical records of tiger sightings in areas bordering CWS (Nagendra 2015).

The first documented tiger presence in BNP was in 2009 (Krishnan pers. obs.), when only pugmarks were observed. In October 2012, additional pugmarks were identified; however, despite camera-trap deployment, no images were captured, and information about the tiger ceased within a month. Three years later, in May 2015, tiger tracks reappeared in BNP's southern wildlife range (Kodihalli), which borders CWS. Over the following months, reports of tiger sightings were more consistent and frequent than in the previous two instances. Through this case study, we aim to document the behaviour and movement of this individual tiger within BNP. Before it could establish BNP as a home range, the main study objective was to identify the tiger, assess reasons for its presence in a non-tiger habitat, and provide management recommendations. Using multiple methods, we focused initially on identifying the tiger, then on evaluating its potential for establishing a home range in BNP.

MATERIAL AND METHODS

Study Area

Bannerghatta National Park spans 260 sq. km and is located south of Bengaluru. It serves as the northeastern terminus of the Eastern and Western Ghats in southern India. BNP is bordered to the southwest by Cauvery Wildlife Sanctuary (1,027 sq. km) in Karnataka and to the southeast by Cauvery North Wildlife Sanctuary in Tamil Nadu. A portion of BNP's northern range includes Bannerghatta Biological Park (BBP), an ex-situ facility that houses a breeding population of captive tigers. BNP's vegetation is tropical dry deciduous and lacks self-originating river systems, relying instead on approximately 250 artificial water bodies (Karikalan 2013). BNP is part of the Mysuru Elephant Reserve and contains approximately 127 elephants (*Elephas maximus*) (Karnataka Forest Department 2023). Other predators in the park include the leopard *Panthera pardus*, dhole *Cuon alpinus*, honey badger *Mellivora capensis*, and sloth bear *Melursus ursinus*. Herbivores in the park include gaur *Bos gaurus*, chital *Axis axis*, sambar *Rusa unicolor*, and muntjac *Muntiacus muntjak* (Krishnan *et al*. 2018)

Data Collection

The study had two primary objectives. The first objective was to identify the individual tiger using camera traps. Given the uncertainty of the animal's movement and the limited number of camera traps available, we focused on establishing a movement pattern by documenting direct and indirect signs of the tiger to maximize capture probability. We recorded the locations and GPS points provided by forest watchers, which were used to create a minimum convex polygon (Nilsen *et al*. 2008) to approximate the animal's movement pattern, aiding in the strategic deployment of camera traps.

The second objective was to document baseline behaviours that could assist in protecting the tiger, particularly in relation to its proximity to human habitation and the occurrence of domestic kills. Over a nine-month period (from May 22, 2015, to January 13, 2016), we opportunistically documented evidence of the tiger's presence, including kills, scat, scrape

marks, and pugmarks. Forest watchers patrolling the park also informed us of both direct and indirect tiger sightings.

We used QGIS (3.30) for mapping and R v. 4.1.2 (R Core Team 2021) for data analysis. This research was conducted in collaboration with the Karnataka Forest Department, which granted permission for the study.

Pugmarks

The pugmarks served two purposes. First, they indicated the tiger's presence in specific locations, aiding in the mapping of its movements and recurring patterns within the park. We recorded the GPS locations and dates of pugmark observations. Second, pugmarks served to identify the individual. Studies have shown that pugmark tracings and photographs can determine a tiger's age and sex (Sharma and Wright 2005; Sharma *et al*. 2003). We measured the pad length (top-to-bottom extremity) and width (left-to-right extremity) by placing a scale beside each impression. To determine if the pugmarks from 2009 and 2012 matched the current tiger, we took multiple Plaster of Paris moulds following Stuart's (2013) methodology.

Camera Trap Images

We deployed motion-sensor camera traps to determine the age and sex of the target tiger, which complemented the pugmark data. Camera traps were set up within the minimum convex polygon and along the primary routes identified by frequent sightings and signs of the tiger. The Karnataka Forest Department provided four camera traps (Model: Cuddeback Digital, E3 Model). Due to the limited number of traps, we followed a variable deployment cycle, initially set at 12 days. As our understanding of the animal's movement improved, we extended this cycle to 15 days at locations where the tiger was repeatedly sighted. Five camera trap locations in the northern BNP were selected based on the frequency of sightings, ranging from two to five occurrences. To capture lateral images for stripe identification, we positioned two camera traps opposite each other, with settings to capture three images per detection, with a 5-second delay between images.

Habitat Usage Information

Over the nine-month study, we opportunistically recorded GPS points of tiger sightings and habitat usage, based on information from forest watchers patrolling areas that varied from 9.72 sq. km to 15.8 sq. km daily. Watchers notified us of recent (<2–3 days old) tiger signs, including scrape marks, scat, and kills. GPS points were plotted on a map to understand the tiger's movement pattern across BNP, and we graded the individual's range based on the frequency of occurrences in different locations.

In addition, we documented kills made by the tiger, noting the prey species, age-sex of prey, habitat type, state of decomposition, percentage of carcass consumed, and distance to human habitation. Proximity to human habitation (public roads or villages) was classified as high (0–100 m), moderate (101–500 m), or low (501–1000 m). This data helped us assess BNP's potential as a sustainable tiger habitat.

Human Settlements and Habitat Information

Since BNP is narrow and surrounded by dense human habitation (with around 77 eco-sensitive villages nearby), it was essential to evaluate the potential for human-tiger conflict and to take steps to protect the tiger. Therefore, we analysed the tiger's locations in relation to nearby human settlements and public thoroughfares.

RESULTS

The primary objective of identifying the individual tiger was achieved through pugmark measurements and confirmed by camera trap images.

Pugmarks

We compared current pugmark tracings to those from 2009 and 2012, revealing they did not match, suggesting a different individual. Over nine months, we collected 88 pugmarks. The average pugmark lengths for the left foreleg, right foreleg, left hindleg, and right hindleg were 14.55 cm (SD ±0.9), 15.05 cm (SD ±1.1), 13.64 cm (SD ±1.3), and 14.11 cm (SD ±0.8), respectively. The average widths were 13.63 cm (SD ±0.9) for the left foreleg, 13.9 cm (SD ±1.6) for the right foreleg, 13.44 cm (SD ±1.1) for the left hindleg, and 12.96 cm (SD ±0.9) for the right hindleg (Fig. 2a). When compared to averages for adult male and female tigers from a different study site (Singh *et al*. 2014), the pugmark lengths corresponded with both male and female measurements, while the widths were consistent with male measurements (Fig. 2b). Variations in limb sizes were likely due to inconsistencies in soil and substrate, where loose and wet substrates lends to more splayed measurements.

Camera Trap Images

The first photographic evidence of the tiger was captured on October 31, 2015, approximately three months after the study began. Although the tiger was only photographed once during the initial twelve trap days, a clear image obtained on November 7, 2015, confirmed the tiger as a subadult male (> 2 years old), defined as an individual independent of its mother but not yet breeding (Karanth 2003). The animal was likely seeking to establish its own territory, with BNP as a possible

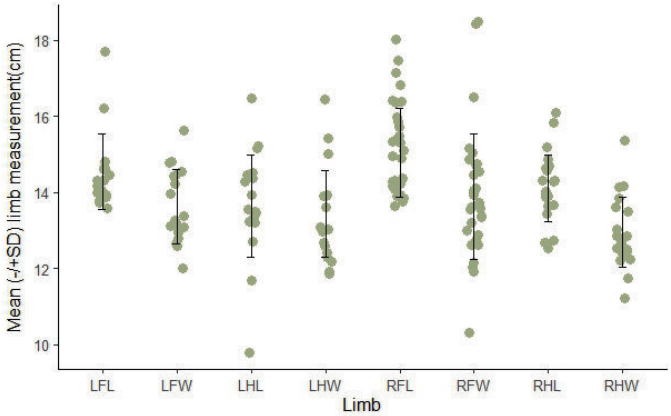

Fig. 2a: The mean and SD for the pugmark length and width measurements. Individual data points indicated as green dots and error bars represent the SD. Left foreleg length: "LFL;" left foreleg width: "LFW;" left hindleg length: "LHL;" left hindleg width: "LFW;" right foreleg length: "RFL;" right foreleg width: "RFW;" right hindleg length: "RHL" and right hindleg width: "RHW"

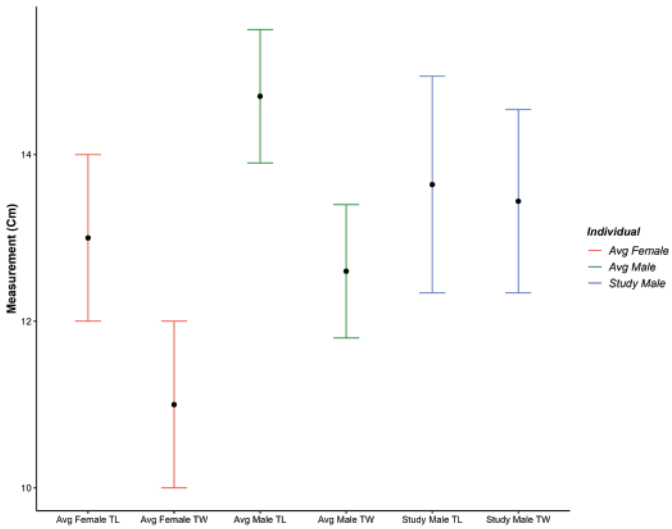

Fig. 2b: Comparing our study animals' total length (TL) and total width (TW) measurements (in blue) to average male (in green) and female measurements (in red) taken from Singh *et al*. (2014). Only left hind leg measurements were compared

home range. Stripe patterns recorded on the individual also enabled identification for future monitoring (Fig. 3a, 3b). No other tigers were identified during the study period.

Habitat Usage Signs

A total of 56 independent tiger observations (fresh signs recorded on different dates) were documented across BNP (Fig. 4). Most observations were pugmarks (66%, followed by camera-trap records (19%, n=11), and three direct sightings (Table 1). Nearly all sightings (92%) were in the northern part of the park (12.56º N). The tiger's movements covered a range from Kagglipura in the north to Neralati in the south, spanning 50 km over 18 days.

Table 1: Distribution of tiger presence across the different methods employed during the study period

Source	Number of independent observations	Number of locations	Occurrence in range
Camera-trap	11	3	Bannerghatta & Harohalli
Kills	5	5	Bannerghatta, Anekal, Harohalli and Kodihalli
Direct sightings	3	3	Bannerghatta
Habitat usage (Pugmarks & scrape signs)	34	24	Bannerghatta, Anekal, Harohalli and Kodihalli
Human settlement	3	2	Bannerghatta

To assess the landscape's potential as tiger habitat, we collected baseline behavioural data, including prey killed by the animal (Table 2). We observed variability in prey size, with the tiger primarily targeting large prey species within the national park. While most of prey were wild animals, the tiger occasionally opportunistically killed domestic cattle grazing inside the Park. Kill locations varied, with some occurring

Fig. 3a, b: The right and left lateral images of the tiger used for identification

Table 2: Prey demographics, status of carcass and proximity to water and human disturbance

Type of kill	Approximate weight (Kg's)	Status of carcass when found (days)	Carcass consumed (%)	Estimated weight consumed (kg)	Proximity to water source (meters)	Disturbance
Wild Pig *Sus scrofa*	50–60	14	5	3	200	High
Sambar *Rusa unicolor*	80–100	7	20	20	20	Low
Domestic Cow *Bos indicus*	150–200	2	30	60	100	Low
Wild Pig *Sus scrofa*	50–60	0.5	5	3	10	Low
Domestic Cow *Bos indicus*	150–200	1	5	40	100	Low

Estimated weight consumed = approximate weight of carcass/ % of carcass consumed. Disturbance regarded as proximity to human habitation (public throughfare/ village) classified using a high (< 0–100 m), moderate (< 100–500) and low (500–1000 m)

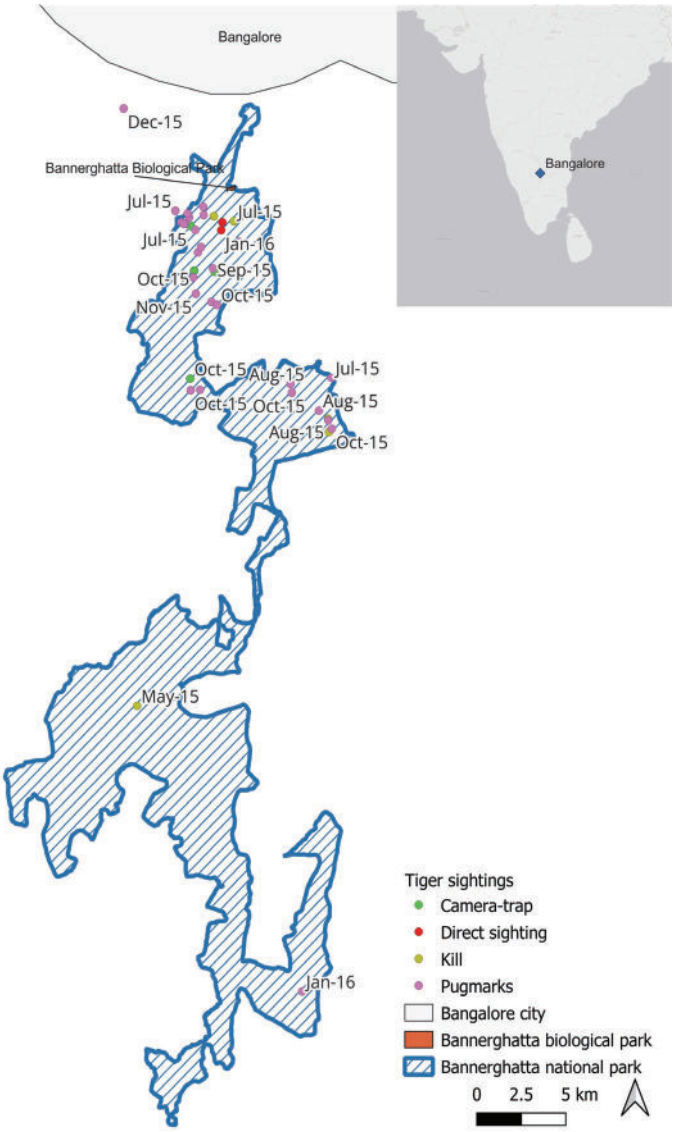

Fig. 4: Spatial-temporal habitat usage signs of the tiger across BNP. Dates on the map indicating the month and year of sighting. Coloured points on the map indicate the type of observation made

in areas of low and others near public road networks, where disturbance was higher.

Human Settlements and Habitat Information

Approximately 45 days after the tiger was first detected in BNP, tracks were found outside the park, about 350 m from the nearest human settlement. The tiger ventured approximately 650 m outside BNP before returning to the forested area (Fig. 4).

DISCUSSION

This case study highlighted the movement and behaviour of a tiger in a novel habitat, observing its activity over nine months from its initial detection in Bannerghatta National Park (BNP). The animal's presence has continued to be recorded up to December 1, 2023, marking eight years since its pugmarks were first noted. This sustained presence indicates that the tiger has been using BNP as part or all of its home range. Based on photographic evidence, the tiger was identified as a subadult male. Camera trap images corroborated pugmark measurements, which showed the length and width of the foreleg pugmarks fell within the range of adult male tigers (Talwar and Usman 2005). The subadult male's activity suggested it was likely exploring BNP to establish new territory, encouraged by the lack of resident tigers and the presence of large ungulates, which make BNP an attractive habitat. Previous studies in BNP show that sambar is the most abundant prey species, further supporting this hypothesis (Krishnan *et al*. 2018).

The prey diversity in the tiger's kills suggests it has adapted well to the environment, targeting large herbivores, consistent with its body size. Most kills were near water sources (within 10–200 metres), possibly indicating a strategy for maximizing prey detection in an unfamiliar environment. Seidensticker and McDougal (1993) outline

three primary events in carnivore predation: prey detection, capture, and consumption. Typically, tigers select prey that overlap spatially and temporally with them (Dou *et al*. 2019); however, in new habitats, adaptive strategies may emerge to optimize prey detection. With limited kill data and an abundance of water sources, it remains uncertain whether the tiger intentionally used these areas to find prey. Future research should examine specific strategies carnivores employ when navigating novel landscapes. Outside this study's timeframe, the tiger was also observed scavenging on a sub-adult female elephant carcass (Dilipkumar pers. obs.), further demonstrating its flexibility to hunt or scavenge based on environmental opportunities.

Managing the metapopulation of tigers and connecting source populations across landscapes is crucial for long-term conservation. Identifying, restoring, and conserving habitat corridors is essential to supporting tiger movements and ensuring population stability. This case study illustrates that connected habitats lacking recent tiger presence can still develop into viable tiger habitats. Even fragmented landscapes like Bannerghatta can provide significant ecological benefits, supporting processes like migration, colonization, and interbreeding. The Cauvery-Bannerghatta Corridor is one such landscape with potential; it includes a source population of around 382 tigers (in a range of 354–411) across 11,100 square kilometres and supports several megafauna, including elephants, gaur, sambar, muntjac, and leopards.

Given the resident male tiger in BNP, we hypothesize that additional tigers may use this landscape. In 2022, internal assessments and camera trap records suggested the presence of another tiger, possibly female, in BNP (Khanna 2022). This observation supports the potential of BNP as a habitat for spill over populations from nearby reserves, presenting an opportunity for expanded research to study tiger behaviour and movement in new habitats.

Limitations

This study was conducted during the first and second wet seasons at BNP, during which pugmark impressions were less frequent or affected by monsoon conditions. Sampling efforts focused primarily on BNP's northern areas due to logistical constraints, creating a sampling bias. The southern range, which adjoins an existing tiger habitat, was challenging to sample due to its extensive area. These limitations, alongside logistical constraints faced by field staff, led to data gaps in this region. Furthermore, the subadult tiger's movement in Bannerghatta might have been influenced by the presence of captive female tigers in the BNP Biological Park, particularly as it neared breeding age. Despite these limitations, our study effectively highlights the tiger's behaviour and movement within BNP. With the possible presence of a newly arrived female, further research can build on this foundation, enabling more intensive sampling across BNP's ranges.

Conclusion

Although only one tiger was detected, this finding validates BNP's role as a "stepping stone" for maintaining the tiger metapopulation in this landscape. BNP and Cauvery Wildlife Sanctuary (spanning Karnataka and Tamil Nadu) likely act as sink populations for tigers from BRT and Sathyamangalam Tiger Reserves. Understanding BNP's potential as a viable tiger habitat will require long-term assessment of the carrying capacities of these source populations. A landscape-based approach to managing and conserving large carnivores like tigers necessitates enhancing habitats around source population sites (Gubbi *et al*. 2017). Habitat connectivity is essential for maintaining genetic diversity, supporting animal dispersal into new habitats, and reducing risks of inbreeding and local extinctions. Thus, landscapes like BNP offer opportunities to expand knowledge on tiger behaviour and movement, contributing to the long-term conservation of the species.

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